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AUTHOR	Cretchley, Patricia; Harman, Chris; Ellerton, Nerida; Fogarty, Gerard
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ABSTRACT

This paper describes a model for effective incorporation of technology into the learning experience of a large and diverse group of students in first-semester first-year tertiary mathematics. It describes the introduction of elementary use of MATLAB, in a course offered both on-campus and at a distance. The diversity of the student group is outlined, types of tasks employing MATLAB are listed, progressive class reaction is traced, and retrospective views expressed in interviews and focus discussion groups are reported. In conclusion, it is argued that careful introduction to MATLAB on attitudes to technology in the learning of mathematics. Recommendations are made for using scientific packages, for learning mathematics, for developing concepts, and for raising levels of involvement and appreciation in large classes. (Author)

Computation, Exploration, Visualisation: Reaction to MATLAB in First-Year Mathematics

Patricia Cretchley, Chris Harman, Nerida Ellerton and Gerard Fogarty
University of Southern Queensland
cretchle@usq.edu.au ; harman@usq.edu.au ; ellerton@usq.edu.au ; fogarty@usq.edu.au

This paper describes a model for effective incorporation of technology into the learning experience of a large and diverse group of students in first-semester first-year tertiary mathematics. It describes the introduction of elementary use of MATLAB, in a course offered both on-campus and at a distance. The diversity of the student group is outlined, types of tasks employing MATLAB are listed, progressive class reaction is traced, and retrospective views expressed in interviews and focus discussion groups are reported. In conclusion, it is argued that careful introduction to MATLAB leads to the effective use of a powerful software tool, and has a positive effect on attitudes to technology in the learning of mathematics. Recommendations are made for using scientific packages, for learning mathematics, for developing concepts, and for raising levels of involvement and appreciation in large classes.

Introduction and Background

Many mathematicians and mathematics educators believe that the use of technology can enliven and revitalise the learning of mathematics. However, those who design early undergraduate mathematics programs face constraints imposed by large classes and limited resources, as well as two further major issues. One is the challenge of coping with the diversity of background, mathematical skills, interests, needs and aspirations that students have on entry. The other is the declining commitment to, and enjoyment of, the study of mathematics. Taylor and Morgan [1] reported on declining skills and uneven preparedness on entry to Australian tertiary mathematics, and drew attention to similar reports in the UK. Forgasz and Leder [2] reported "a general decline in the enjoyment of mathematics between school and university", in a study of five Australian universities.

Enrolment patterns are changing. Course design has become a delicate balance: under conditions of diminishing resources we try to support and encourage under-prepared students, while trying to stimulate and maintain the interest of talented students. And we do this in the face of stiff competition from other subject areas, which offer favourable career prospects.

The University of Southern Queensland is a growing dual-mode university, balancing its commitment to supportive on-campus teaching with the strength and experience it has developed in distance education. The university attracts many mature-age and international students alongside Australian school-leavers. Algebra & Calculus I is the primary first-semester mathematics unit for students entering Engineering, Mathematics, Science, and Business, covering topics in calculus, vectors, linear equations, and matrix algebra. Well over 300 students register, but many of the external students de-register without penalty, finding themselves unable to make the time commitment necessary to pass.

Against this background, the decision was made to employ technology in the unit, in an attempt to assist students to develop concepts and skills. Existing reports have often supported the view that effective use of computers in the learning of mathematics can motivate students at both ends of the spectrum of skills and ability, even those quite indifferent to mathematics. USQ experience included trials of computer-based learning over several years, using *Mathematica,* and the programming language *APL.* Many believe that the use of available and accessible scientific software empowers students in ongoing courses, and it was felt that introduction to elementary use of such a package would be more appropriate for the needs and aspirations of this large and very diverse group, than currently available teaching-specific software and materials.

MATLAB, which is used in a number of higher level undergraduate units, is the software package most favoured by Engineering and Applied Mathematics at USQ. In 1997, pilot trials in a few Algebra & Calculus I tutorials which support the four lectures per week, revealed its strong potential as a supplement. In 1998 it was decided to support MATLAB in the unit for on-campus students. Positive experience in that trial led to extension of support for its use to distance students in 1999.

A range of elementary tasks employing MATLAB to support the learning of the parallel Calculus and Linear Algebra components of the unit, was integrated into five assignments and the weekly tutorials. Basic use of MATLAB was demonstrated in lectures, and a brief guide supplied, covering the commands and syntax needed. Many students in this early mathematics unit have little or no experience of programming and file-management, so no work of that kind was expected. Students were offered access to the Classroom Version of MATLAB for the duration of the semester, but were encouraged to buy the Student Version. On-campus students were supported by their tutors in computer laboratories during the second hour of their weekly tutorial. During the first hour students were assisted in a classroom, doing standard mathematical tasks. Distance students had to rely on pre-arranged telephone tutorials, and assistance by telephone, email, newsgroup, or fax, on request.

It was made clear to students that they would not be examined on MATLAB usage, and that they were free to use alternative software or graphics calculators. They were told that notebook computers and graphic calculators would be permitted in their open book examination, but were warned that for equity reasons, questions would be designed so that they did not need the support of technology. They were also told that no computers would be allowed into their other examination.

Searches reveal very few published reports on such early tertiary use of MATLAB. Use in more focused Linear Algebra courses is better documented. Trials of DERIVE, MAPLE, and Mathematica are reported quite widely, but MATLAB has different strengths and potential syntax problems for students not yet familiar with matrix algebra. Because of the extra effort and cost of supporting such an add-on, and the paucity of such studies of software in the current literature, it was felt that appropriate research into the effects of introducing the use of powerful scientific software would be valuable. A research project was therefore undertaken to investigate the effect of the use of MATLAB on early undergraduate students' attitudes to mathematics and learning, invoking the skills of a team of specialists in the appropriate disciplines of mathematics, education, and psychology. Analysis reported here constitutes some preliminary findings from this in-depth study. The project is supported by a USQ Project Team Research Grant.

Research Design and Methodology

A broad range of instruments was used to gather information and monitor the effects of this trial on students' skills, views, and approaches to mathematics and learning. Breadth of information was sought via pre-and post- tests given to all students, and a broad range of assignment tasks. Depth was established via focus discussion groups and case studies which included interviews.

A survey instrument was developed to assess students' views on learning mathematics, their experience using computer software for learning mathematics, and their self-efficacy in mathematics and the use of computers. It comprised 68 self-report items that employed a Likert-style response format, with options ranging from 1 (strongly agree) to 5 (strongly disagree). It was administered at the commencement of the unit, and with the last assignment. 447 students responded to the pre-survey, reflecting much higher enrolment than usual but numbers dropped back to around average when well over a hundred de-registered without penalty within the first month. 172 responded to the post-survey. Views were also established by means of feedback questions on assignments, self-selection of some assessment tasks, interviews, and focus discussion groups.

A number of reasons are postulated for the sharp increase in enrolment and subsequent quick drop in numbers, and these need further investigation, but the unexpected increase in enrolment resulted in delays in students accessing their study materials and textbooks. Though extensions were granted freely, some students were disheartened by being unable to meet deadlines. The introduction of a technology component is likely to have contributed to their difficulty, but the timing of many of the de-registrations indicates that for many students, this was probably not the major cause.

Mathematical skills were assessed on entry to the unit, using a test which had already been administered to incoming engineering students over a number of years. 213 students responded. The unit examination was used as a post-test of skills: 260 students sat the examination.

To monitor ongoing reaction to different types of tasks over the semester, questionnaires were included in all but the first of the five assignments. These instruments comprised six questions, three matched pairs, inviting students' views on which exercises or types of tasks had been *"most helpful for learning", "not helpful for learning", "most enjoyable or interesting", "most boring", "difficult but rewarding"*, and *"too difficult or frustrating to be worthwhile"*. Students were free to respond with any views they felt appropriate. No responses pointing at MATLAB or anything else were solicited in any way. 154 students responded with Assignment 2, 52 with Assignment 3 (which only the external students submitted), 94 with Assignment 4, and 135 with Assignment 5.

Face-to-face focus group discussions were held with five groups of students: three groups of on-campus students (30 students in total) and two groups of external students (13 students in total). Forty students representing a spread of skills and attitudes on entry to the unit, were interviewed individually, either face-to-face or by telephone, 25 of those studying on-campus, and 15 externally.

Results

Survey Data. Analysis of the differences between pre- and post- survey responses forms the next stage of this research, and is not reported in this paper. However, to establish the distribution of their views about the use of computer software for learning, at the end of their technology experience in this unit, responses to two of the post-survey items are offered below. A total of 172 students responded on a five-point Likert scale.

For the item *" I found computer software helpful for my learning of mathematics"*
45 indicated strong agreement, 76 agreed, 25 were neutral, 4 disagreed, and 2 strongly disagreed.
For the item *"I will use computer software again by choice"*
64 indicated strong agreement, 72 agreed, 28 were neutral, 6 disagreed, and 2 strongly disagreed.

Focus Discussion Groups and Interviews. Because this trial used MATLAB so early in their course, it was the only unit of study in the semester that required its use. Most of the students engaged willingly in the set tasks, and many used MATLAB for other purposes too, and indicated that they will use MATLAB voluntarily in the future. A few indicated they did only what they had to with MATLAB and would avoid it if they could. Very few students (mostly females) reported dislike.

Frequent references were made to greater clarity of understanding following computer exploration, graphing and calculation, to the added visualisation as an aid, and to the speed with which graphing and computation is accomplished. Many reacted to technology exploration as though they were "playing". Roughly half the students used MATLAB more extensively than required: to check answers to hand-calculations, to explore graphs further, and to evaluate expressions. A few who had the Student Version used the Symbolic Toolbox access to the MAPLE kernel. Some enthusiastic students expressed very strong interest and enjoyment, and used it well beyond unit needs. Very few took on the challenge of writing their own programs, or even basic loops: they were content at this level to settle for command-line work, even if this was repetitive.

A clear majority (over 75%) of those participating in discussion groups valued the use of MATLAB, and supported continuation along current lines. Similar trends emerged in the interviews. On-campus students, who received much better support, reported more positively than external students, who offered a much wider spread of views. They experienced a host of problems early in the unit, including delays in receiving texts and materials, and this disadvantage made their learning experience more difficult. Some felt the technology experience was too big an extra load. A significant number, however, were very computer literate, and anxious to accommodate and explore the use of technology in their learning of mathematics. Some expressed the view that they expect this kind of experience to be an integral part of their future. The overall vote was for continued inclusion of this experience, but it was clear that external students need much more support early in the unit.

Assignment Questionnaires. These traced student reaction to the range of tasks over the semester. Students were free to offer responses to six open questions which did not solicit any reference to technology at all. The range of responses was wide: from specific questions, to words as broad as "Algebra". Very few patterns were observed in the responses but there was frequent and unprompted incidence of the word "MATLAB" or direct reference to questions that focused on MATLAB exploration. The questions were designed in pairs, to facilitate comparison between positive and negative views. Table 1 offers the incidence of MATLAB responses.

These figures reflect a much higher incidence of "MATLAB" responses to the positive questions than to the matched negative questions in most of Assignments 2 and 3. Entries in Table 1 relating to Assignment 4 and 5 reflect an even balance of reaction to the MATLAB tasks. A look at the types of tasks reveals broad student support for those tasks which support visualisation and exploration, mixed reaction to routine tasks which confirm matrix algebra and theorems, and distaste for tasks which reveal technology weaknesses or focus on issues of machine storage and computation. The level of frustration apparent in Assignment 3, which was submitted by distance students only, may well reflect the relative difficulty for the latter.

Table 1: Incidence of "MATLAB" Responses in Questionnaires (as a % of number of respondents)

Assignment Number (number of respondents)	2 (154)	3 (52 externals)	4 (94)	5 (135)
Which type of exercises or tasks have you found:				
most helpful for learning?	23 %	17%	16%	13%
not helpful for learning?	7 %	7.5%	14%	15%
most enjoyable or interesting?	44 %	17%	14%	14%
most boring?	10 %	6%	13%	13%
difficult but rewarding?	18 %	4%	2%	0%
too difficult or frustrating to be worthwhile?	12 %	11%	4%	6%

Table 1 responses validate views offered in the interviews and general trends evident in the discussion groups. Table 2 is a general overview of reaction to the range of MATLAB tasks.

Table 2: Overview: Types of Tasks and Students' Reaction

	MATLAB Tasks	**Reaction**
Ass 1	Graphing functions in the plane: local and global behaviour	Strong positive
Ass 2	Graphing lines and planes in 3-D: exploring their equations and intersections	Strong positive
Ass 3	Riemann Sums (on-campus students only)	Strong positive
	Row-reduction, solving systems of linear equations	Strong positive
	Polynomial curve-fitting and estimates	Mixed
Ass 4	Matrix algebra, inverses	Good/mixed
	Textbook exercises hinting at, but not fully revealing, the effect of format differences, rounding difficulties and responses to alternative commands	Mixed: poor levels of observation and understanding
Ass 5	Visualising and calculating areas under curves	Strong positive
	Determinants and applications	Good

Some explorations were particularly successful: three-dimensional graphing of lines and planes was cited frequently, as was row-reduction and matrix algebra without the tedium of repetitive hand calculations. On-campus students acknowledged the strength of repeated computer calculations of Riemann Sums in development of the definite integral. (Distance students were not asked to do this.)

Despite attempts to encourage students engaged in this trial to learn some concepts at the computer, they expressed clear preference for mastering the basics away from the computer, some verbalising feelings of distraction when they felt crowded with technology. Students knew that there would be no computer access in one examination, and there were frequent references to the need for hand-skills. Almost all expressed a wish to explore new concepts and techniques on paper first, then to use technology to expand, explore, and confirm. Despite the volume of tasks inviting use of technology in the unit, they expressed firm belief in the value of hand-calculation and saw the computer as an aid, not a replacement. Some acknowledged that they might feel lazier about hand-calculation if much greater access to technology was permitted.

Summary and Conclusions

This study revealed wide acceptance of use of technology as an add-on. Most students expressed positive feelings about the effect this type of use of technology has on their learning. Evidence was found of strong educational impact of introduction to the use of MATLAB. Except in the case of some external students, early frustration levels over access to the package and syntax difficulties subsided quite quickly, and students offered more evidence of heightened interest and enjoyment and value for learning, than counter-evidence (Table 1). On-campus students gave generally strongly positive reports on the use of MATLAB in the unit, even those who use graphics calculators. Distance students expressed a much wider range of views, had more difficulties to deal with, and some found that using MATLAB increased the burden.

Students come into tertiary study with beliefs entrenched by years of experience of mathematics learning, and these attitudes are difficult to change. Shuck [3] likened these to "chains". Use of technology as a supplement, in the manner described here, did not appear to shake the conviction that they learn better away from the computer and need hand-skills. These views seemed to be a result of deeply held beliefs, the nature of their experience of technology, and the nature of the unit examinations. Not examining students on their use of MATLAB may well have contributed to these convictions. Certainly this approach dispelled much of the stress associated with syntax and access difficulties, and there was evidence that this promoted a climate of interest in and enjoyment of their use of technology.

To retain the motivating effect of technology, there must be sufficient support for its use, and tasks set need to include variety and an element of surprise. Students responded positively to enhanced opportunity for visualisation, ease of graphing and computation, and exploration. Routine practice, rather than exploration, turned many students off, and many were not ready to address potential difficulties or errors arising from the use of technology. Deep immersion in technology is perhaps still too sudden a change of learning experience for many students. Students responded well to some degree of control over how much technology they used for learning, and this provides evidence that good course design should accommodate such choices.

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Organization/Address: University of Southern Queensland, AUSTRALIA	Telephone: (+61) (7) 4631-5526	FAX: 4631-5550
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